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BACKGROUND INFORMATION FOR A PROPOSED STUDY ON REFERTILIZATION OF ROAD SLOPES FOR EROSION CONTROL REVEGETATION

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STUDY BY . . . . .ENVIRO-CHEMICAL BRANCH
WATER QUALITY SECTION
PHYSICAL INVESTIGATIONS UNIT

SUPERVISOR . . . . .DOUGLAS M. PARKS, P.E.

REPORT BY . . . . .JOHN EHSAN
JR. CIVIL ENGINEER(ROTATION)

PREFACE

Fertilizers are commonly specified for use on road slopes to assist in the establishment of grasses and woody plants for erosion control and aesthetics. Caltrans specified about 750,000 pounds of fertilizer in 1977 on highway projects. Usually, the fertilizer is selected on a judgment of nutritional needs of the vegetation without necessarily having a knowledge of the soil chemistry. The primary elements considered are Nitrogen (N), Phosphorus (P), Potassium (K), and the acidity or alkalinity of the soil (pH). In some cases, the fertilizer specifications used for upcoming projects are based on previous specifications for various district projects.

In early 1976, TransLab recognized the possible need for testing selected soil samples from slopes that were planned for landscape planting or erosion control vegetative treatment in order to more accurately determine nutrient needs. A memorandum was sent to the Office of Landscape Architecture suggesting distribution to the districts of one-page Fact Sheet announcing the availability of nutrient testing services at TransLab Chemistry Section. The Fact Sheet was distributed to the districts by the Office of Landscape Architecture on April 5, 1976.

Because of the high cost for laboratory testing (estimated $300/sample) and the long turn-around time to receive test results (2-3 weeks), only one district utilized the TransLab service. It was obvious that a faster and less costly testing procedure was needed. Also, it would be desirable to have an instrument or test procedure that could be operated in the district by district personnel.

A portable soil chemistry test kit was purchased in March 1977 from Hach Chemical Corporation for evaluation. The kit, which cost $495 in 1977, is capable of testing N,P,K, lime requirement, and soil pH. TransLab field tested several soil samples prior to sending the kit to districts 02, 03, 05, 09 and 11 for evaluation.

Results of the district testing showed that soil chemistry information can be very useful in developing a fertilizer specification. The information was published in a TransLab research report entitled "Evaluation of a Soil Chemistry Test Kit for Use in Specifying Fertilizers for Erosion Control Vegetation on Road Slopes," December 1978 (1).

As a follow-up to that study, TransLab included a $30,000 reserve research project in the 1980-81 to 1982-83 HP & R Proposed Environmental Research Program called "Fertilizer Application Study" (see Appendix). The purpose of the study was to develop refertilization procedures for obtaining optimum revegetation of road slopes. In the summer of 1980, a Junior Civil Engineer on rotation assignment, was given the task of putting together background information upon which the request for proposal preparation could be formulated. The work was performed under the direction of Douglas Parks, Supervisor of the Physical Investigations Unit, TransLab.

The following is a report of the study findings.

Richard B. Howell
Senior Materials & Research Engineer
Water Quality Section
TransLab

ABSTRACT

A review of background material on refertilization and nutrient needs of soils on road slopes was undertaken as a preliminary step towards submitting a request to develop a research proposal on this subject. The research project is included in the FY 80-81 TransLab research program as a reserve project entitled "Fertilizer Application Study" (see Appendix). This report discusses the background information on physical and chemical properties of soil, essential elements for plant growth, and field studies by Caltrans and others.

Roadside slopes consist of subsoil materials which are nearly always low in plant nutrients to support vegetation. Nitrogen (N) is virtually absent in most subsoils because they are low in organic content. Phosphorus (P) and Sulfur (S) are usually low and beneficial to the plants. An application of needed nutrients will: (1) help vegetative mat absorb runoff water; (2) help roots to bind the soil; (3) increase vigor and beauty of vegetation; (4) prevent takeover by low-fertility bunchgrass; (5) increase growth during the first growing season; and (6) assure better winter survival.

Too little emphasis is placed on refertilization as a roadside maintenance tool in most Caltrans Districts. Districts 01, 02 and 03 and District 11 are the only districts that have worked with refertilization in the past few years.

District 01 has formed an Erosion Control and Revegetation Committee to identify problem slopes and develop mitigation plans. Part of the mitigation includes reseeding and fertilizing.

Vickie Bacon, Landscape Architect of District 02, set out 3'x3' experimental plots in conjunction with a TransLab study along Hwy. 299 near Buckhorn Summit, west of Redding. She compared grass growth, size, coverage and vigor of refertilized areas to non-refertilized areas. Her studies indicate that refertilization successfully improved the growth of grasses used for erosion control.

TransLab and District 03 contracted with the University of California, Davis, Department of Environmental Horticulture, to study revegetation of road slopes in the Lake Tahoe Basin. Caltrans Landscape Maintenance in San Diego has also done some refertilization work. In 1978, District 11 refertilized about 1000 acres of roadside slopes in the San Diego area.

A review of the literature shows that a number of direct and related studies were undertaken by other agencies such as: The University of California at Davis (Kay, Leiser); Soil Conservation Service (Edmunson, Clary, Slayback); US Forest Service (Gallup); University of California (Reisenauer); Washington State Highway Commission and Washington State University Agricultural Research Center.

Nearly all agencies recommend refertilization as a tool for better vegetation and plant growth. Although refertilization was proven effective, the degree of its effectiveness has not been determined. The reason for this is due to the myriad of variables involved. Some of these include: rainfall intensity, slope steepness, slope aspect, time of refertilization, soil reaction (pH), plant species, soil texture and composition.

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INTRODUCTION

Refertilization of roadside slopes for better grass growth is very important in increasing stand density, vigor, seed germination and maturity. The more sterile and arid the site, the more important refertilization becomes (2). Nitrogen (N) is virtually absent in most slopes and Phorphorous (P) and Sulfur (S) are usually low, yet beneficial to the plants; therefore, refertilization should be practiced until adequate coverage and development occurs.

1. DO ALL ROADSIDE SLOPES NEED PERIODIC REFERTILIZATION?

   Supplemental fertilization should be used where grass seed is grown directly on sandy or gravelly subsoils (3). As a general rule, bare spots on road slopes and scarce plant life affecting both aesthetic values and potential erosion control is an indication that refertilization is needed (Burgess Kay).

2. HOW ARE AREAS SELECTED FOR FERTILIZER APPLICATION?

   Major roadsides should be inspected systematically for deteriorating vegetative cover. Significant exposure of bare ground at the peak of spring growth indicates potential problems and the soil should be tested for pH and mineral content (3).

3. WHAT FERTILIZERS ARE BEST FOR ROADSIDE SLOPES?

   The actual fertilizer formula used is not critical as long as it adds up to about 80 lbs/acre N, 100 lbs/acre P_2O_5 and 77 lbs/acre S. This rate can be achieved with 500 lbs of (16-20-0), 400 lbs ammonium sulfate plus 500 lbs single superphosphate, 240 lbs ammonium sulfate plus 500 lbs single superphosphate, or limitless other combinations (4).

4. WHAT RATES OF FERTILITY ARE BEST FOR ROADSIDE VEGETATION?

The amount of fertilizer should be limited to what the plant can use under the limitation of available moisture in the growing season. Coverage and density needs of grass on the slopes must also be considered. About 400 to 500 lbs/acre of (16-20-0) is highly recommended for most slopes in California (5).

5. HOW OFTEN SHOULD REFERTILIZATION BE REPEATED?

Roadside slopes should be refertilized as infrequently as possible unless needing maintenance. In some areas, like San Diego, application of fertilizer has been recommended once a year for excavated slopes and once every two or three years on embankment slopes (6). Other areas can be refertilized once every three to five years depending on rainfall intensity (Robert Slayback). Perhaps visual inspection of roadside slopes with more respect to vegetation needs is the best indication of the refertilization period. Further research is needed on the rate and frequency of fertilizing roadside slopes.

6. IS IT NECESSARY TO TEST FOR NUTRIENT NEEDS BEFORE APPLYING FERTILIZER?

There is no need to test for all nutrients (N,P,S,Ca,K, etc.) in the soil. California soils are usually deficient in nitrogen (N) and possibly (P). Sulfur (S) is inexpensive and essential for the grass. It should be added automatically. Grass does not respond well to Ca, K and other nutrients; therefore, it is not economical to include them in fertilizer formulations. In conclusion, a test for the presence of phosphorous (P) is the only nutrient test necessary (Kay).

7. IS THERE A PREFERRED TIME FOR FERTILIZER APPLICATION?

Timing is more important for grass because of extreme mobility of the fertilizer nitrogen (N). Fertilizer should be applied when the plant needs it the most. Spring is the ideal time since root growth is very active and N uptake is high. Early fall is another desirable period. There is less loss of nutrients due to leaching and wash-out in spring (April) than in fall (October).

8. HOW AND WHEN DO YOU EVALUATE THE EFFECT OF REFERTILIZATION?

Visual inspection of grass coverage, counting the number of plants, and measuring plant height to make a comparison of fertilized vs. non-fertilized plots, are the common methods of evaluation for erosion control vegetation. The effect of refertilization should be evaluated at the time when rainfall is highest, and at the end of the annual year.

SOIL AND NUTRIENTS

Summers in California are very dry and hot. Rains generally begin in October with the heaviest amounts coming in the winter period of December to February. There is a wide variation in quantity and distribution of rainfall from year to year.

The magnitude of benefits of refertilization on slopes will depend upon the fertility of the site, the species of the plants present, physical and chemical characteristics of the soil, annual rainfall and rainfall intensity, slope steepness and temperature patterns.

In general, when talking about nutrient needs and the effect of fertilizer on plants, general knowledge of the following four characteristics is helpful: soil properties, plants, weather, and nutrients available.

Due to the scope and limitations of this report, discussion of plants and weather is eliminated and more emphasis is given to soil, nutrients, and the relationship between soil, vegetation and fertilizer. The following brief discussion of soil and nutrients, which is adapted from various soil and plant text books, is critical background information to further study of fertilization and its practical application.

1. WHAT IS SOIL?

According to the National Limestone Institute, Inc., (13) soil is "The collection of natural bodies occupying portions of the earth's surface that supports plants and has certain properties due to the combined effect of climate, a living matter, acting upon parent rock materials over long periods of time."

Soil, then is actually very, very small pieces of rock (minerals), decomposed plant and animal residue (organic matter), air and water. On a percentage basis, soil is about 45% minerals, 20-30% air voids, 20-30% water and 5% organic matter. Living organisms must also be included such as earthworms, insects, and bacteria. This living portion may represent 1% of the weight of a given amount of soil.

2. SOIL-NUTRIENT-PLANT RELATIONSHIPS

Physical as well as chemical properties of soil influence the amount of nutrients contained in the soil, and to a certain extent, affect the availability of the nutrients to plants.

- <u>Soil Texture</u>
  The size distribution of soil particles, directly influences the amount of nutrients absorbed by the soil. The finer the soil texture, the more nutrients (and water) will be held. To apply the same amount of nitrogen a sandy soil would require more frequent application at smaller rate than would a clay soil.

- <u>Soil Depth</u>
  Soil depth determines the nutrient and water-holding reservoir available to the plant. The deeper and wider a plant is able to root in the soil, the more water and nutrients will be available.

- <u>Soil Structure</u>
  The arrangement of soil particles influences root exploration and absorption ability of plants. A compact soil, or one lacking an open granular structure, may restrict root growth and activity by limiting water and air movement and by physically impeding growth.

Chemical Properties of Soil

Indications are that certain elements are necessary for the normal growth of plants. These ESSENTIAL ELEMENTS must be present in forms usable by plants and in concentrations optimum for plant growth. In addition, there must be a proper balance among the concentrations of the various soluble nutrients in the soil. Too much calcium, for example, may interfere with phosphorus and boron nutrition, or may encourage leaf chlorosis because of a reduction in the availability of the soil iron, zinc, or manganese.

According to a University of California publication (16), 16 elements have been found essential for plant growth (Table 1). They are essential because:

- In the absence of any one of the elements, the plant fails to complete its life cycle.
- Each element has a direct effect on the plant, not an indirect effect, such as repelling insects, which might prevent completion of the plant's life cycle.
- Each element is specific, it cannot be replaced or substituted by another element.

As shown in Table 1, carbon and oxygen are supplied to plants from carbon dioxide in the air. Oxygen is available to the plant either directly from the air or from the soil atmosphere. Hydrogen comes from water absorbed from the soil. The remaining thirteen elements come from the soil and are referred to as plant nutrients. Six are used in relatively large quantities and are thus referred to as Macronutrients. Other nutrient elements that are needed in small quantities are called Micronutrients. Brady (7) states that micronutrients are used by "higher plants in very small amounts". The author (7) also

TABLE 1 - ESSENTIAL ELEMENTS FOR PLANTS

Source	Element	Symbol		Form Available to Plants
Air & Water	Carbon	C		CO_2
"	Oxygen	O		O_2 and H_2O
"	Hydrogen	H		H_2O
	Macronutrients			
Soil	Nitrogen	N	Nitrate	NO_3^-
"	Phosphorus	P	Ammonium, Phosphate	NH_4^+, $H_2PO_4^-$
"	Potassium	K	Potassium	K^+
"	Calcium	Ca	Calcium	Ca^{++}
"	Sulfur	S	Sulfate	$SO_4^=$
"	Magnesium	Mg	Magnesium	Mg^{++}
	Micronutrients			
Soil	Manganese	Mn	Manganese	Mn^{++}
"	Zinc	Zn	Zinc	Zn^{++}
"	Boron	B	Borate	$H_2BO_3^-$
"	Copper	Cu	Copper	Cu^{++}
"	Iron	Fe	Iron	Fe^{++}
"	Molybdenum	Mo	Molybdate	$MoO_4^=$
"	Chlorine	Cl	Chloride	Cl

mentions that "except for iron and in some cases manganese, micronutrients are found sparingly in most soils, and their availability to plants is often very low."

- Soil Testing

The objective of soil testing is to appraise the level of elements available in soil without first having to grow a plant. Melsted (8) defines soil testing in a broad sense, as "any chemical, physical, or biological measurement made on soil."

Soil test results are factual data characterizing the fertility status of the area represented by the sample. This leads to a definition of objectives in field sampling. According to Peck (9), "soil testing is an advisory service which guides the farmer in his soil fertility program and provides him with information for making decisions."

A good analysis is dependent upon a careful, accurate, and representative sampling of soil. For a fertility assay, apportion the area to be tested into sites that are similar in growth characteristics and general appearance. Obtain a sample by compositing about ten cores or thin soil slices taken from a number of locations in each site. Turf or litter should be removed from the soil surface before sampling. The depth of sampling depends on soil type and rooting characteristics of the plants. In a report by the University of California (6), the following method for taking samples is mentioned:

- Turf: Take samples at 0 to 3 inch and 3 to 6 inch depths. For special sites, such as greens, take sample at 0 to 2 inch, 2 to 4 inch and 4 to 6 inch depths.
- Flowers and shrubs: Take sample at 0 to 6 inch and 6 to 18 inch depths.

The result of the soil test must be interpreted by a person experienced in evaluating laboratory data in relation to the plants and soil involved.

The TransLab bought a soil nutrient kit and had several districts participate in testing soils in their districts to evaluate the usefulness of the kit in determining fertilizer specifications. A report was published on the work entitled "Evaluation of A Soil Chemistry Kit for Use in Specifying Fertilizer for Erosion Control Vegetation on Road Slopes", Report No. TL-78-31, November 1978 (1).

- pH of Soil

According to Brady (7) the pH value of a solution is the Logarithm of the reciprocal of the hydrogen ion concentration. It may be stated conveniently as:

$$pH = Log \frac{1}{[H^+]}$$

This means that pH is simply a measure of acidity as influenced by the hydrogen ion. The number associated with the term "pH" represents the total soil acidity. The numerical values range from 0 to 14. At the middle of the scale (pH 7.0) soil is neutral in reaction, while below 7.0 the reaction is acidic and above 7.0 it is alkaline. A soil with a pH of 6.0 is 10 times more acidic than one with a pH of 7.0. Also a pH of 9.0 is 10 times more alkaline than one with a pH of 8.0 and 100 times more alkaline than one with a pH of 7.0.

According to E. O. McLean (10), the concept of pH is based on the ion product of pure water. Water dissociates very slightly:

$$H_2O \rightleftharpoons H^+ + OH^-$$

$$Kw = [H^+]\,[OH^-] = 10^{-14} \text{ at } 23°C$$

He explains the symbols Kw and [] are, respectively, the ion product for water and the concentration of each component indicated in moles per liter of solution. Since $[H^+] = [OH^-]$ in pure water at 23°C , each is equal to $\sqrt{10^{-14}} = 10^{-7}$ to the extent that $[H^+]$ exceeds $[OH^-]$ in a solution, it is acidic. Conversely, when $[OH^-]$ exceeds $[H^+]$, the solution is basic or alkaline.

McLean also mentioned the pH of pure water at 23°C is 7 while that at 100°C is 6.0 and at 0°C is 7.5. Hence, there is an obvious need for taking pH measurement at near-room temperature and for adjusting pH meters to the temperature of the solution being measured.

Since most of the plant-essential elements in a soil reach maximal or near maximal availability in the pH range of 6-7 and decrease both above and below this range, the soil pH is an indication of relative availability of plant nutrients. Thus, it seems fair to say that soil pH is both a symptom of the soil's condition and a cause of many of the reactions which occur.

W. C. Lowdermilk (11) states that soil reaction is important to plant growth for several reasons:

a) its effect on nutrient availability
b) its effect on the solubility of toxic substances such as aluminum)
c) its effect on soil microorganisms
d) and direct effect of pH on root cells (which effects the uptake of nutrients and waters).

When the pH level in the soil is changed, the availability of soil elements is also changed. Figure 1 shows the general relationship between pH and availability of nutrients (15).

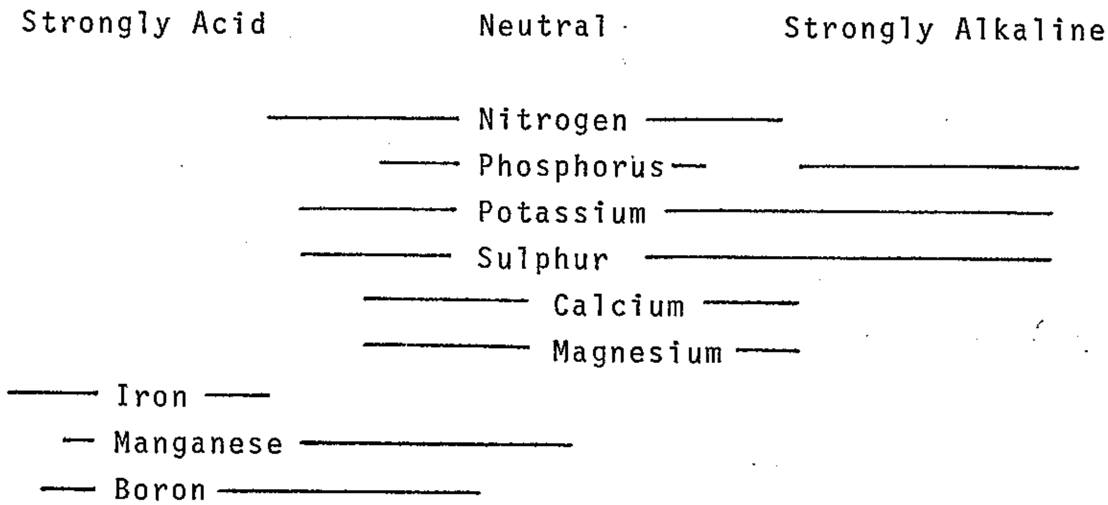

Fig. 1 - How pH Affects Availability of Plant Nutrients

Cation Exchange Capacity of the Soil

Cation is the word used to describe a plant nutrient in the soil. For example, limestone consists primarily of calcium carbonate ($CaCO_3$). When exposed to water in the soil, the calcium carbonate separates into halves, or ions. As they separate, the calcium ion becomes positively charged (Ca^{++}) and the carbonate ion becomes negatively charged($CO_3^{=}$). By definition, a cation is a positively charged ion, and an anion is a negatively charged ion. Virtually all plant nutrients, when added to the soil, undergo a change similar to the example given for limestone. Nitrogen does not exist in the soil as pure nitrogen. Rather, it is in the form of the ammonium cation (NH_4^+) or the nitrate anion (NO_3^-).

The soil has a negative charge. It acts like a magnet to hold these positively charged cations that are added in the form of lime and fertilizer. If the soil was not capable of attracting and holding these nutrients, they could easily be lost through leaching during the first rain. As a plant root grows through the soil, these cations are "exchanged" from the soil to the root and are ultimately used by the plant in the growth process. Cation exchange capacity then, tries to measure the capacity of the soil to hold these exchangeable cations. If a soil has a high cation exchange capacity (C.E.C.), that soil is said to possess many negative charges and can hold many cations for plant use.

Some of the more common cations include hydrogen (H^+), calcium (Ca^{++}), magnesium (Mg^{++}), ammonium (NH_4^+) and potassium (K^+). Of these cations, hydrogen is held most lightly on the soil particle. As the amount of hydrogen increases from acid-forming fertilizer, plant respiration, and organic matter decomposition, it forces out other cations and eventually builds up in quantity causing high soil acidity. If allowed to remain, the soil cannot hold other nutrients and the plants cannot grow properly. Large applications of limestone replace the hydrogen with calcium and magnesium which reduces the acidity. In turn, other nutrients can easily displace some of the calcium and magnesium on the soil particle and hold it for plant use (13).

- <u>Soil Temperature</u>

The temperature of the soil markedly effects the soils usefulness to the plant. In cold soil, chemical and biological rates are low. Biological decomposition is at a near standstill thereby limiting the rate at which nutrients such as nitrogen, phosphorus, sulfur, and calcium are made available. For example, nitrification does not begin in the spring until the soil temperature reaches about 40°F. The most favorable limits are 80-90°F. Also, plant processes, such as seed germination and root growth, occur only above certain critical soil temperatures. Likewise, the absorption and transport of water and nutrient ions by higher plants is adversely affected by low temperatures.

Recently, the California Agricultural Experiment Station pinpointed the growth of grass during the winter with soil temperatures. It was found that grass growth increased very little when the average soil temperature dropped below 45°F, whether fertilized or unfertilized. The grass fertilized with nitrogen and phosphorus showed the greatest increase in growth compared with unfertilized grass when the average soil temperature was between 47°F and 55°F. When the soil temperature went above 55°F, the difference between growth of fertilized and unfertilized grass decreased.

3. FERTILIZER (Nutrients)

Webster's dictionary defines fertilizer as "a substance (like manure or a chemical mixture) used to make soil more fertile". The Soil Conservation Service (11) defines fertilizing critical areas (roadside slopes in our case) as: "adding of natural or manufactured plant nutrients to the soil to aid in the establishment of vegetative cover on silt-producing and severely eroded areas to stabilize the area so as to reduce damage from sediment and runoff to downstream areas, to prevent loss of soil by wind and water, and to improve wildlife habitat."

- Essential Elements From The Soil

  As it was explained in the section on chemical properties of soil, there are 16 essential elements for plant growth. Thirteen of them come from the soil and are divided into macronutrients and micronutrients. Because of an insufficient response of grass to micronutrients, the discussion of micronutrients is eliminated in this section and more emphasis is placed on macronutrients.

Nitrogen, phosphorus, and potassium are commonly supplied to the soil as fertilizers. They are called primary elements. In the same way, calcium, magnesium and sulfur are referred to as secondary elements. "Complete Fertilizer" refers to a fertilizer that contains nitrogen (N), phosphorus (P), and Potassium (K). The analysis on the fertilizer-bag label indicates the percentage by weight of the three nutrients. They are always listed in the same order: 1) nitrogen (as element N), 2) phosphorus (as P_2O_5), and 3) potassium (as K_2O_5).

- <u>Factors Controlling The Growth Of Higher Plants</u>

The essential elements are only one of the environmental factors influencing the growth of plants. In addition to the absence of disease and freedom from insect pests, six such external factors are generally recognized (Figure 4): a) light, b) mechanical support, c) heat, d) air, e) water, and f) nutrients. The soil is an agent in supplying either wholly or in part, all of these external factors with the exception of light (7).

It is well to remember that plant growth depends upon a favorable condition of these factors and that any one of them, if out of balance with the others, can reduce or even entirely prevent the growth of plants. Furthermore, the factor which is least optimum will determine the level of plant growth. This principle is sometimes called the "principle of limiting factors".

The concept of limiting factors is also applicable with nutrient elements. We must be concerned not only with the supply of a given element but also with the relationship of this supply to all other factors which may affect plant growth. For example, nitrogen-deficient grasses usually have S concentrations well above critical levels. Only when sufficient N has been applied to correct the N deficiency will S deficiency of grasses occur (Soil Conservation Service).

Even though other elements are present in more than adequate amounts, plant growth can be no higher than that allowed by the most limiting nutrient. When quantities of that limiting nutrient are added, the level of plant growth is raised until it is controlled by the next most limiting factor (7).

A) Nitrogen:

Nitrogen (N) is the element most commonly deficient in soil. Plant response to nitrogen fertilizer is almost universal. The amount of nitrogen in the soil is small, while the quantity withdrawn annually by plants is comparatively large.

Of the macronutrients usually applied in commercial fertilizers, nitrogen seems to have the quickest and most pronounced effect. It tends primarily to encourage above ground vegetative growth and to impart to the leaves deep green color. Brady (7) said, "with all plants, nitrogen is a regulator that governs to a considerable degree the utilization of potassium, phosphorus and other constituents."

The amount of nitrogen available to plants (present in a soil) varies considerably depending on the balance between nitrogen present, the amount added, and the amount lost. According to a University of California report (6), nitrogen becomes available to plants through: 1) mineralization of organic matter, 2) addition of fertilizer, and 3) fixation of atmospheric nitrogen by bacteria.

Nitrogen is taken up by plants primarily as nitrate (NO_3^-) or ammonium (NH_4^+) ions. Plants can utilize both of these forms of nitrogen in their growth processes.

According to Western Fertilizer Handbook (15), most of the nitrogen taken up by plants is in the nitrate form. There are two basic reasons for this. First, nitrate nitrogen is mobile in the soil and moves with soil water to plant roots where uptake can occur. Ammonic nitrogen, on the other hand, is bound to the surface of soil particles and cannot move to the roots. Second, all forms of nitrogen added to soils are changed to nitrate under proper conditions of temperature, aeration, moisture, etc., by soil organisms.

B) Nitrification:

It occurs in the soil in several forms: ammonium (NH_4^+), nitrate (NO_3^-), nitrite (NO_2^-), nitrogen gas (NO)↑, and organically-bound nitrogen (Org N). The predominant form is organic-nitrogen which usually accounts for 97 to 99% of the total nitrogen. In this form, the nitrogen is not available to plants but acts as a storage medium that is slowly mineralized to usable nitrogen compounds by microorganisms in the soil. The first step in the process is ammonification which is the conversion of organic-nitrogen to ammonium-nitrogen. Under favorable conditions, ammonium N is converted first to nitrite N, then rapidly to nitrate N, which is the most readily usable form for plants.

The reaction occurs readily under conditions of warm temperature, adequate oxygen and moisture, and optimum pH.

$$2NH_4^+ + 3O_2 \xrightarrow[\text{oxidation}]{\text{enzymic}} 2NO_2^- + 2H_2O + 4H^+ + \text{Energy}$$

$$2NO_2 + O_2 \xrightarrow[\text{oxidation}]{\text{enzymic}} 2NO_3^- + \text{Energy}$$

At 75°F, nitrification may be completed in one to two weeks. At 50°F, 12 weeks or more may be required. For optimum conversion of nitrification, pH must be maintained between 5.5 and 7.8. The relative nitrification by bacteria varies according to the soil pH as follows:

Soil pH	4.0	7.0	9.0
Relative Nitrification	Poor	Good	Poor

Certain soil or weather conditions, such as compacted soil, poor drainage, unfavorable pH, or cool temperature interfere with nitrification while ammonification continues. This situation allows a build up of ammonium N levels in the soil which is itself valuable since it can be utilized by plants and provides for rapid nitrification when the condition improves.

C) Denitrification:

Under anaerobic conditions caused by excessive moisture and/or soil compaction, certain bacteria are capable of removing oxygen from chemical compounds in the soil to meet the needs of their life processes. When nitrate is used, various gases are formed such as nitrous oxide (N_2O), nitric oxide (NO) and nitrogen (N_2). The reaction can be represented as follows:

$$\begin{tikzcd} NO_3^- \arrow[r] & \underset{\text{nitrite}}{NO_2^-} \arrow[r] \arrow[d] & {} \arrow[r] \arrow[d] & {} \arrow[r] & \underset{\text{nitrous oxide}}{N_2O} \\ & \underset{\text{nitric oxide}}{NO} & \underset{\text{nitrogen}}{N_2} & & \end{tikzcd}$$

D) Phosphorus:

With the possible exception of nitrogen, no other element has been as critical in the growth of plants in the field as has phosphorus. Phosphorus is required for seed formation, root development, plant maturity and resistance to certain diseases.

Phosphorus is absorbed by plants as $H_2PO_4^-$, $HPO_4^=$, or $PO_4^{\equiv}$, depending upon soil pH. According to Brady (7), availability of phosphorus to plants is determined by the ionic form of this element. The ionic form in turn is determined by the pH of the solution in which the ion is found. Thus, in a highly acid solution, only the H_2PO_4 ions are present. If the pH is increased, first the $HPO_4^=$ ions and finally $PO_4^{\equiv}$ ions dominate. This situation is shown by the following equations:

$$\underset{\text{(very acid solutions)}}{H_2PO_4^-} \rightleftharpoons H_2O + HPO_4^= \rightleftharpoons H_2O + \underset{\text{(very alkaline solutions)}}{PO_4^{\equiv}}$$

Soil particles contain a considerable amount of inorganic phosphate complexes that break down to more readily usable forms over long periods of time. In some soils, phosphorus is "tied up" in the soil and is not available to plants. In this case, high rates or more frequent application of phosphorus may be needed to overcome this "tie up".

According to the U. S. Department of Agriculture, phosphorus fertilizer may be applied in large amounts and at any time during the year because in contrast to nitrogen, it does not leach out of the root zone. It was also stated that carryover responses have been measured for as long as 10 years.

E) Potassium:

Potassium is important for strong stems and stalks and a well developed root system, as well as the production and movement of plant sugars and starches. Potassium is taken up by plants in the form of potassium ions (K^+), sometimes referred to as potash, which is an oxygen-containing compound (K_2O).

Potassium may be added to the soil by applying granite dust, potash rock and wood ashes. Dried fish scraps and seaweed provide natural sources.

FIELD STUDIES

1. District 02, Buckhorn Summit

As part of a TransLab erosion study, District 02 set out 3'x3' experimental plots on Hwy. 299 slopes in Trinity County near Buckhorn Summit in May 1979, to determine the effect of refertilization on encouraging native species. The three cut slopes selected were P.M. 67.6 (Site 1), P.M. 68.1 (Site 2), and P.M. 71.6 (Site 3). All were north facing slopes, with a slope angle of about 1-1/2:1 and consisted of decomposed granite.

The slopes were originally seeded and fertilized in 1977-78. A handfull of (16-20-0) fertilizer was sprinkled over each plot in May 1979. A corresponding control plot was left untreated. There was little or no grass within the plots at the time they were refertilized.

Rainfall in this area varies from about 60 inches/year near P.M. 72 to about 40 inches/year near P.M. 66. A below normal rainfall was experienced in the 1978-79 winter (20") and 1979-80 winter (33") as recorded with a Weather Measure Precipitation Gage located at P.M. 69.16 (Buckhorn Mountain Maintenance Station).

An evaluation of the vegetation was taken in September 1979 and May 1980. The results were reported in September 1980 by Vickie Bacon (District 02 Landscape Architect) as follows:

SITE 1:

In September 1979, the overall quality of grass growth was deteriorating, grass density and vigor was spotty on the control area. The refertilized plot was noticeably greener, although not much grass was growing.

In May 1980, the slopes appeared to have no new spring growth except for spotty areas of native grasses. The grass cover was growth from the previous year that at this time was laying on the slope. The refertilized plot contained new growth of native grasses.

SITE 2:

In September 1979, a dramatic contrast in color, vigor and density of grass appeared at the refertilized plot. The area directly adjacent to this plot had almost no grass.

In May 1980, the overall slope had very little new spring growth, and here again, at the refertilized plot there was a dramatic contrast between the density and vigor of grass growing within the plot and that of the areas surrounding it.

SITE 3:

In September 1979, there was little or no change since the last review over the total slope area or within the plot area. New grass was emerging within the refertilized plots. The grass height was still very low but the color of grass in the refertilized plot was greener compared to the adjacent areas.

In May 1980, the grass growth within the refertilized plot was very vigorous and dense. The surrounding area had no standing grass.

Vickie Bacon made the following conclusions: "Between the first and second year after refertilization, the quality of grass cover declines. Without additional fertilization, new grasses may not emerge in future seasons but the old growth and the roots of the existing grass will continue to protect the slope from surface erosion". (Communication of Sept. 1980.)

2. District 11

District 11 has been practicing refertilization since 1970 with satisfactory results. In March of 1978, District 11 (San Diego) used a helicopter to refertilize 1000± acres in Escondido, Descanso, and San Diego at a total cost of $81,000.

Locations: Areas refertilized were located on freeway right-of-ways in six general locations or approximately 12 sub-areas. Specific locations of the sites and their descriptions are as follows:

Route			Area (Acres)
I-5	PM 26	Ardath Road	10
	High slopes. Very little growth until fertilized a number of years ago. 2 years' fertilization needed to fill in bare areas and strengthen present plants' growth.		
	PM 23.66	Gilman Drive to PM 30.06	54
	Fertilized once by Buffalo the last year A. Z. Clark was here. The vegetation along the bottom of slopes up to about 50' is lots heavier than top that hasn't gotten any. 3-year program.		
	PM 30.06 to 30.69		49
	High slopes. Never been fertilized. Rivulet type erosion. Fertilization needed if these slopes are to cover over. 3-year program.		
	PM 30.06 to 32.90	Carmel Valley Road	67
	Some of this area has developed a weed cover. Other areas on the cut slopes are not growing anything. Three-year program to bring area to the point natives will cover.		
Rte 52	PM 0.0-3.76		93
	Route is through San Diego natural park. Fertilization is to promote both planted and native plants to grow. Under the 12 program, 9 tons of fertilizer has been proposed. This will fertilize 18A, leaving a balance of 93A.		
Rte 67	PM 1.25-2.80	Woodside	
	Cut slopes. Interchanges, etc.		
	PM 2.80-5.23	Mapleview Street	
	Sandy area-vegetation rather sparse.		

Rte 75	PM 12.60-13.00 Large bank with some ice plant on it. 1 year fertilization at 600 lb. rate.		3
	PM 13.98 Ice plant in need of fertilization. 2 year program at 600 lb. rate.	Silver Strand State Park, U.C.	2
	PM 13.98 On lt. next to park and ocean Native ice plant. Fertilized 8-10 years ago. Needs a booster. 1 year at 600 lb. rate.		7
Rte 94	PM 4.7-7.89 Area never fertilized. Plant growth is nearly all weeds. Natives not coming in considering age of the road. Fertilization No. 2 priority. Probably 2 years of normal fertilization would be sufficient.		50
	PM 9-10 Area just never developed sufficient native vegetation to cover. Some weeds have grown in on the south facing slopes. 3 year program.	Left side	5
	PM 10.11 Heavy weed population. 3 year fertilization program.	125/94 Interchange	30
	PM 10.95-13.25 This is several years old. With a good cover of natives, we should never have to do anything more to it. 3 year program.	Avocado Interchange-Wide median	45
Rte 117	PM 3.60-5.14 New road. Soil very erosive. Needs a 3 year+ program of fertilization.	I-805 Interchange	59
I-805	PM 0.6-3.65 Lots of cuts and fills. Soil poor. 3 year fertilization program needed.	Otay Valley Road	40
	PM 5.8-8.0 Same as above.	Bonita Road	66
	PM 8.8-10.9 Same as above.	South of 252	60
	PM 18.1-20.3 Some sparse vegetation coming in. 2 year fertilization program recommended.	Route 163	80

PM 23-26.10 La Jolla Village Rd. 108
This includes La Jolla Village Dr., Governor Dr., Route 52. Not much regrowth. Erosion needs 3 years of fertilization.

PM 26.10-28.5 Tie-in with I-5 60
Area fertilized once years ago. Fair cover consisting mainly of weeds. Fertilization needed to bring in the natives. 2 year program.

The contract was made with Golden State Helicopters, Inc., (contract No. P-11985) on February 8, 1978, as follows:

1. Contractor would supply 500 tons of ammonium sulphate (21-0-0) as a bulk material with a screening size of at least 85%-22 mesh and not over 1%-35 mesh.

2. Contractor furnished all trucks, water tankers, manpower, loaders to do this work. Payment would be by ton, in-place, at the rate of one-half ton per acre.

3. Contractor supplied three Sling King Fertilizer Spreader buckets. Two had a capacity of 2000 pounds with the backup bucket a minimum of 1500 lbs. capacity.

4. Contractor provided two fully qualified helicopter pilots with California AG licenses and FAR part 133A, B, and C, and 137 qualified. Minimum of 2000 hours agricultural application experience were also required.

The work was completed on April 28, 1978, at the cost of $163.25 per ton of fertilizer in-place. The total cost was $81,722.74.

According to Leonard Zink, Landscape Maintenance Specialist in San Diego, the soil was tested for nutrient needs before applying fertilizer. Ammonia sulphate (21-0-0) was found to be the most effective formulation for the slopes. He also stated, "Refertilization is the best method to control erosion vegetation in the San Diego area. It saves water in irrigated areas and helps aesthetics." (July 31, 1980).

On August 13, 1980, Leonard Zink and Tom Ham (Landscape Architects in District 11) and John Ehsan from TransLab visited the sites on Routes 94, 117, 52 and I-5. There was a dramatic contrast between density and vigor of native grasses 2 years after the treatment.

In May 1978, D. E. Delvery (District Maintenance Engineer) wrote a memorandum to R. G. Rypinski (Legal Department) in regard to the helicopter fertilization program. He stated, "The helicopter fertilization program is now concluded for the 1977-78 fiscal year. We anticipate continuing with this work for the next year for the following reasons:

1. We wish to encourage growth on barren highway slopes to reduce erosion and improve appearance.
2. We wish to encourage growth of native plants so as to crowd out tumbleweeds. The latter can be a traffic hazard if motorists dodge them as they roll across the highway, particularly at night.
3. The use of a helicopter is much less expensive than spreading the material by hand. While a truck-mounted blower can be used in some places, it can only project the granules about 30 to 50 feet from the edge of the road."

   He also stated, "We plan to go back to using a small helicopter next year. It is more maneuverable than the larger one used this year. So we should get a better spread without spillage beyond the planned areas".

   A medium helicopter of 800 to 850 horsepower with a payload capacity of 2500 to 3000 was used during 1978 refertilization work.

Due to 81 law suits by local people and different agencies for the 1978 refertilization, District 11 stopped the refertilizer applications.

3. Lake Tahoe Experiments

In April, 1974, Dr. Andrew T. Leiser, of the University California at Davis, as a segment of the TransLab-District 03 research "Revegetation of Disturbed Soils in the Tahoe Basin", selected a slope at Luther Pass (P.M. 1.9) on Highway 89, just south of Lake Tahoe, to revegetate for erosion control (12). The site was at the top of the cut slope, which was considered to be one of the most difficult areas to revegetate. A combination of instability plus drought accounts for this fact. Grass establishment by seeding and fertilizing was particularly poor on this portion of the cut. Grass transplants with three species of rhizomatous wheatgrass was felt to be the most effective way of vegetating this cut slope. The test compared fertilizing with one gram of nitrogen per hole (as 21-8-8, a combination of slow and fast release nitrogen), and no fertilizer, as well as two sizes of peat pots. Observations made on June 20, 1974 indicated that "Fertilization is imperative." From one to two inches of erosion had occurred on the unfertilized plots as well as where the fertilized, small peat pots were used. The peat pots were exposed one to two inches. By contrast, there was no erosion on fertilized, large peat pot transplants. This was attributed to the additional size of the plants in large peat pots as well as increased vigor due to fertilization.

In 1977, TransLab requested Burgess Kay, Wildland Seeding Specialist with U.C. Davis, to undertake an evaluation of the several grass experiments in the Tahoe Basin and vicinity. Mr. Kay concludes from evaluation of the experimental plots that "we use the most productive grasses and fertilize them well." His report is included in the Appendix.

4. Washington State Highway Commission

On May 10, 1968, Washington State Highway Commission and Washington State University Agricultural Research Center, made a study entitled "The Establishment of Vegetation on Non-topsoiled Highway Slopes in Washington" (2). In one portion of their study, two 20x30 ft. plots in two replications were established in a 3:1 cut slope along Interstate 5 near Tangleswilde in Thurston County, Washington. The soil was a droughty spanaway gravelly loam with the following nutrients: P = 0.8ppm, K = 30ppm, Ca = 1.5meq/$_{100\ gr.}$ soil. The objective of this study was to determine the effect of various combinations of N, P, and K on banks which had been seeded one year previously.

The area was originally planted to a mixture of English perennial ryegrass, Chewings Fescue, and white clover at 80# of seed per acre. A slurry of seed, 1200# of wood celulose fiber per acre, and 300# of (12-12-12) fertilizer per acre were originally applied.

The 20x30 ft. plots were refertilized using nitroform (38% urea formaldehyde) and urea (46% N). Phosphorus was applied from single super phosphate (20% P_2O_5) and potassium from muriate of potash (60% K_2O). Fertilizer treatments consisted of 850# of N and 87# of P_2O_5 and K_2O per acre in all combinations. All fertilizers in the refertilization experiment were applied by hand broadcasting methods.

The grass and clover were yellowish in color, stunted, and covered no more than 50% of soil surface on April 11, 1969 (check point). A pronounced improvement was recorded in 1970 showing readings of 7 to 10 on refertilized plots compared to 3 to 5 for control plot (1=bare soil, 10=100% cover; 1=yellow, 10=100% excellent color).

From these data, it is evident that refertilization of poor soil is important to stand establishment, density, and color. As a conclusion, the report stated "refertilization should definitely be practiced until adequate coverage and development has been produced".

5. TransLab Nutrient Test Kit Study

From March to June 1978, TransLab set up a small scale field experiment in five districts in cooperation with the Offices of Landscape Architecture and Landscape Maintenance. The experiment was to determine the value of information on soil chemistry in specifying fertilizer for landscape plantings and erosion control. Four districts (02, 05, 09, and 11) each selected sites and tested the soil for N, P, pH and lime requirements using the TransLab soil chemistry test kit.

The Districts tested soil samples from the following locations:

District	County	Location Route	Post Mile
02	Shasta	44	0.5
	"	299	24.8
05	San Luis Obispo	101	15.9
	" " "	1	48.8
	" " "	227	9.9
09	Mono	158	3.2
	"	395	37.9
	Inyo	395	24.0
11	San Diego	15	Near Escondido*
	" "	52	.5 mile E of Genesee Ave.
	" "	117	E of Picador Avenue

*Area proposed for construction

District 02 Test Results:

	Site 1 (Hwy 44)	Site 2 (Hwy 299)
pH	6.3	7.6
Lime requirement, tons/acre	0	0
Potassium, lbs/acre	180	330
Phosphorus, lbs/acre	10	15
Ammonia Nitrogen, lbs/acre	35	80
Nitrate Nitrogen, lbs/acre	58	15

District 05 Test Results:

	Site 1 (SLO 1)	Site 2 (SLO 101)
pH	4.6	5.1
Lime Requirement, tons/acre	1.75	0
Potassium, lbs/acre	160	Not tested
Phosphorus, lbs/acre	135	200
Extractable Phosphate, lbs/acre	42	100
Ammonia Nitrogen, lbs/acre	65	100
Nitrate Nitrogen, lbs/acre	2	25

	Site 3 Sample 1 (SLO 227)	Site 3 Sample 2 (SLO 227)
pH	8.0	7.4
Lime requirement, tons/acre	0	0
Potassium, lbs/acre	360	255
Phosphorus, lbs/acre	250	205
Extractable Phosphate, lbs/acre	40	62
Ammonia Nitrogen, lbs/acre	75	90
Nitrate Nitrogen, lbs/acre	5	5

District 09 Test Results:

	Site 1 (Mno-395)	Site 2 (Mno-158)	Site 3 (Iny-395)
pH	7.9	7.8	6.2
Lime requirement, tons/acre	0	0	0
Potassium, lbs/acre	0	320	780
Phosphorus, lbs/acre	47	45	255
Ammonia Nitrogen, lbs/acre	190	350	92
Nitrate Nitrogen, lbs/acre	27	33	68

District 11 Test Results:

	Site 1 (SD-15)	Site 2 (SD-52)	Site 3 (SD-117)
pH	7.2	5.4	8.5
Lime requirements, tons/acre	not run	not run	not run
Potassium, lbs/acre	150	250	320
Phosphorus, lbs/acre	40	75	50
Ammonia Nitrogen, lbs/acre	not run	not run	not run
Nitrate Nitrogen, lbs/acre	0	5	6

The kit was evaluated in terms of usefulness in providing information to district designers for specifying fertilizers and application rates. The kit was found to be easy to use. However, due to the limited time period, it was not possible to answer all the questions regarding test results and comparative fertilizer designs with and without the soil chemistry information. Information from this study was published in a TransLab research report in December 1978 (1).

6. District 01 Soil Nutrient Tests

District 01 has formed a Revegetation and Erosion Control Committee to identify severely eroding highway slopes and to formulate a treatment plan. In 1979, the Committee identified 12 Sites consisting of 26 highway slopes that needed treatment.

At the request of the Committee, the Water Quality Section of TransLab performed a field study of the sites in September 1979. During the field survey, physical measurements were taken of each slope, soil samples collected, the sites were photographed including special features, and the causes of erosion were noted.

The results of the soil nutrient tests were as follows:

Site	County	Route	Post Mile		N	P (lbs/acre)	K	NO_3	pH
1	Lake	20	43.2	(1)	190	100	500	10	5.5
				(2)	205	75	360	55	5.9
	"	"	43.65 right		235	70	650	15	5.7
			43.65 left		232	55	420	12	7.4
			43.85		108	40	390	8	6.5
			44.07		101	45	200	16	6.9
2	Mendocino	101	43.7		104	15	20	14	5.3
3	"	1	83.1		75	55	100	0	3.7
			83.2		193	80	120	13	3.8
			83.5	(1)	260	160	220	90	4.7
				(2)	250	45	320	90	4.9
			83.53	(1)	165	40	325	25	5.1
				(2)	172	130	300	12	7.5
4	Mendocino	101	76.28	(1)	108	35	90	8	7.5
				(2)	107	55	340	17	6.0
			76.85	(1)	65	40	200	0	4.1
				(2)	75	45	170	5	7.1
			77.25	(1)	103	30	25	8	7.1
				(2)	155	45	100	20	5.5
			77.55	(1)	85	45	350	10	4.0
				(2)	80	35	380	10	6.6

Site	County	Route	Post Mile	(lbs/acre) N	P	K	NO_3	pH
5	Mendocino	101	102.15	(1)118	180	270	8	5.4
				(2)106	28	430	6	8.1
			102.3	(1)160	50	280	0	7.8
				(2)124	38	170	4	5.7
			102.7	80	25	450	0	7.9
6	Humboldt	101	51.9	(1)137	100	600	17	7.5
				(2)265	90	400	15	4.6
7	Humboldt	299	12.1	205	20	450	5	3.7
			12.2	96	35	340	6	3.7
			13.0	(1) 70	30	50	20	3.7
				(2) 90	50	375	20	4.1
8	Humboldt	299	10.6	95	35	350	15	8.0
9	Humboldt	299	32	(1) 93	25	40	8	8.1
				(2)100	25	140	30	7.4
10	Humboldt	96	5.2	(1) 67	20	200	2	4.7
				(2)105	50	100	35	6.1
				(3) 90	30	70	15	8.1
				(4) 68	35	70	8	5.0
11	Del Norte	199	14.9	(1)180	50	70	10	4.2
				(2) 93	50	160	3	5.1
12	Del Norte	199	33.4	(1)185	60	230	10	4.0
				(2)170	125	230	3	3.6

All soil samples showed a nutrient deficiency in N and NO_3, and in P. It appears that a fertilizer application of 16-20-0 at 500 lbs/acre would meet the nutrient needs of the soil. In some cases, the high acidity (pH of 3.6 to 5.5) is significant in formulating a treatment plan for these slopes.

A report of the field survey was prepared for District 01 (17).

SUMMARY OF FINDINGS

Refertilization should be used for most roadside slopes seeded with grasses and small plants (with the exception of slopes that are very steep or slopes with stability problems). Fertilizers have very little or no effect on slopes with larger bushes, shrubs and trees. Soil may be tested for pH, N, P, and K before applying the fertilizer to ascertain the extent of any nutrient deficiency. However, the main nutrient that needs to be analyzed is P since most soils are already known to be deficient in N. The soil pH was also a very important piece of information for specifying seed mixtures.

In general, the amount of fertilizer applied to the slope should consist of 80 lb/acre N, 100 lb/acre P_2O_5 and 77 lb/acre S; this rate can be achieved by using 500 lbs/acre of 16-20-0. The fertilizer specified must also contain the sulfur (S) component.

Even though the test result provides the most appropriate fertilizer formulation for any particular site, in some cases it is not economically feasible to use such a fertilizer formulation because special fertilizer formulations may be more expensive than that of common ones available on the market.

The information developed in this study can be used as background data for preparing a detailed Work Plan for the HP&R research project "Fertilizer Application Study".

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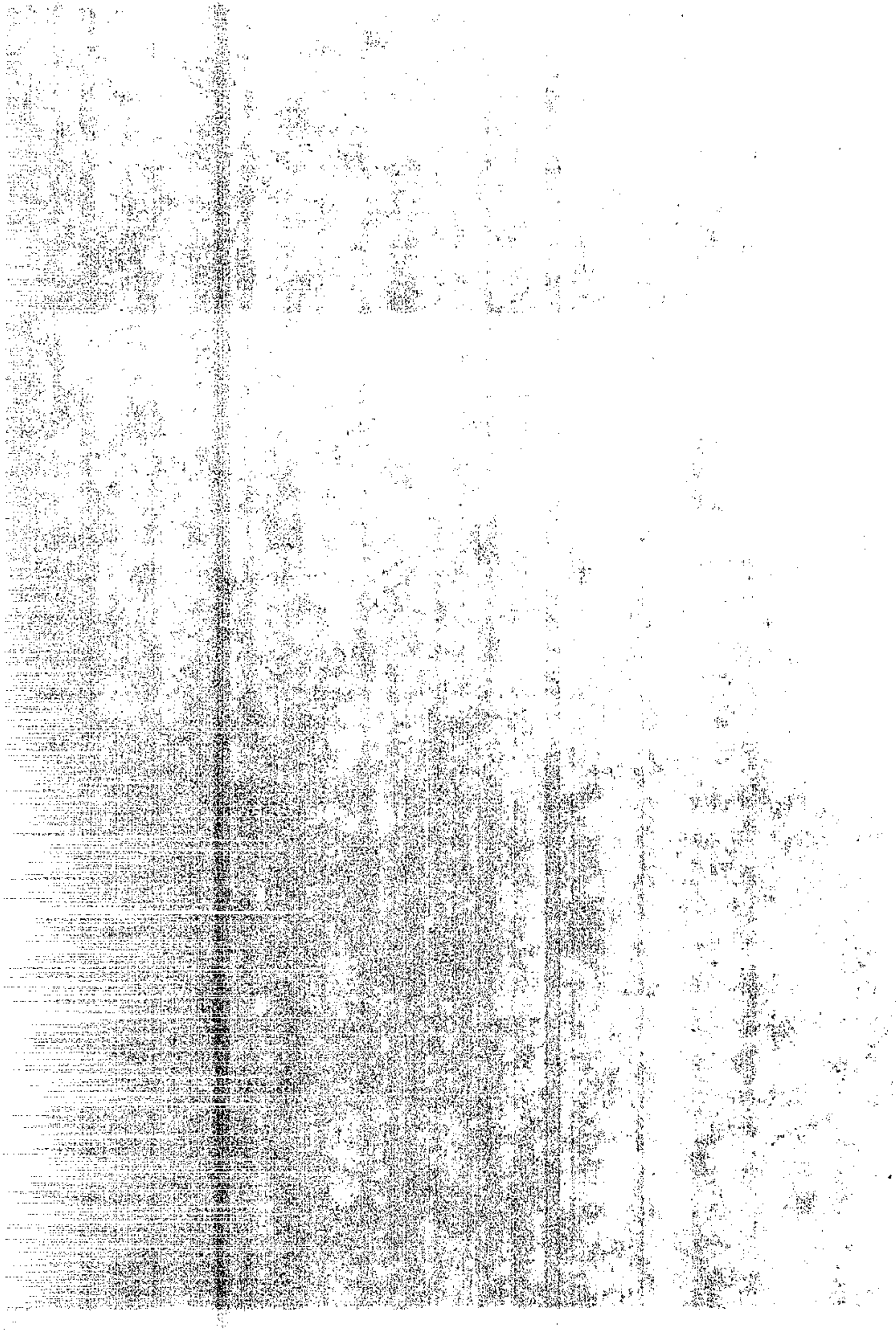
APPENDIX



TO: G. E. Gray, Chairman
Caltrans Research Committee

Date: 7/9/80

FROM: DEPARTMENT OF TRANSPORTATION
Office of Transportation Laboratory

SUBJECT: Funding Request to Prepare a Research Proposal

TITLE: Fertilizer Application Study

OBJECTIVE:

Evaluate the most effective method of refertilizing road slopes for erosion control vegetation.

JUSTIFICATION:

Examination of soil on road slopes in regard to nutrient needs will help in the specification of fertilizers. Indications are that refertilization of some slopes may result in better revegetation. Several slopes have severe erosion a few years after treatment because of nutrient deficiencies resulting in poor vegetative cover. TransLab has previously studied a Nutrient Test Kit for use by the districts (Report CA-TL-78-31, Dec. 1978) and conducted studies in District 01, 02, and 03 regarding soil nutrient needs. It appears that this research will provide guidelines to landscape architects and maintenance personnel in refertilizing road slopes for erosion control vegetation.

The loss of revegetation in time due to nutrient deficiencies results not only in the loss of the initial erosion control treatment investment, but also incurs additional maintenance costs in cleaning up eroded sediment and culvert/drainage cleanouts. Consequently, this project has the potential to financially benefit Caltrans.

PRINCIPAL INVESTIGATOR: Richard B. Howell, Senior Materials & Research Engineer

CO-INVESTIGATOR(S): Douglas M. Parks, Associate Materials & Research Engineer

Amount $3,000 F.Y. 1980-81 TOTAL COST $30,000 DURATION 2 YEARS

STATE* ______ FHWA X INCLUDED IN 1980-81 F.Y. BUDGET

APPROVAL RECOMMENDED

ROBERT O. WATKINS, Chief Transportation Laboratory	/ / (Date)	G. E. Gray, Chairman Caltrans Research Committee	/ / (Date)

cc: x CCPeterson x RBHowell ___ ______ ___DDH:

x ECShirley x DMParks

DC-TL-1127 (Rev. 8-80)

*If State explain why.

Report on Grass Seeding and Management Studies

Lake Tahoe June 1977

B. L. Kay

INTRODUCTION

A number of erosion control plantings were made in the Tahoe area during the period 1970 to 1973. Plantings include the watersheds on Caltrans cut slopes at Luther Pass and Chamberlain, U.S. Department of Transportation, Kingsbury Grade, Placer Co. road in Ward Valley and grass nurseries at the Tahoe Keys subdivision and the El Dorado Co. Airport. This report compares the results of these plantings and changes since the evaluation which I made in 1975. A discussion and summary appear at the end of this report.

I. Watersheds

The cooperative USGS watershed areas at both Chamberlin and Luther Pass were first seeded to grass in the fall of 1972 to provide temporary site protection during shrub establishment. The original seed mix was Potomac orchardgrass 15 lb/acre, Durar hard fescue 15 lb/acre, and Sodar streambank wheatgrass at 20 lb/acre. The original fertilizer application was 16-20-0 at 250 lb/acre (QR Sept. 1972 p. 1-2). This grass mix was designed to provide temporary cover during shrub establishment.

Portions of these watersheds were reseeded at later dates, sometimes with a different seed mix, following excessive disturbance from shrub transplanting (mostly in the spring), or stand failure. All were refertilized at least once. Slow release (38-0-0 + SSP @ 80 lbs/acre N) and 16-20-0 (40 lb/acre N) fertilizers were compared (QR Sept. 1973 p. 2-3).

A comparison of erosion control fabrics (excelsior and Hold/gro) and hydroseeding was made at two locations.

Following are observations on these watershed on June 7-8, 1977. A summary appears in Table 1.

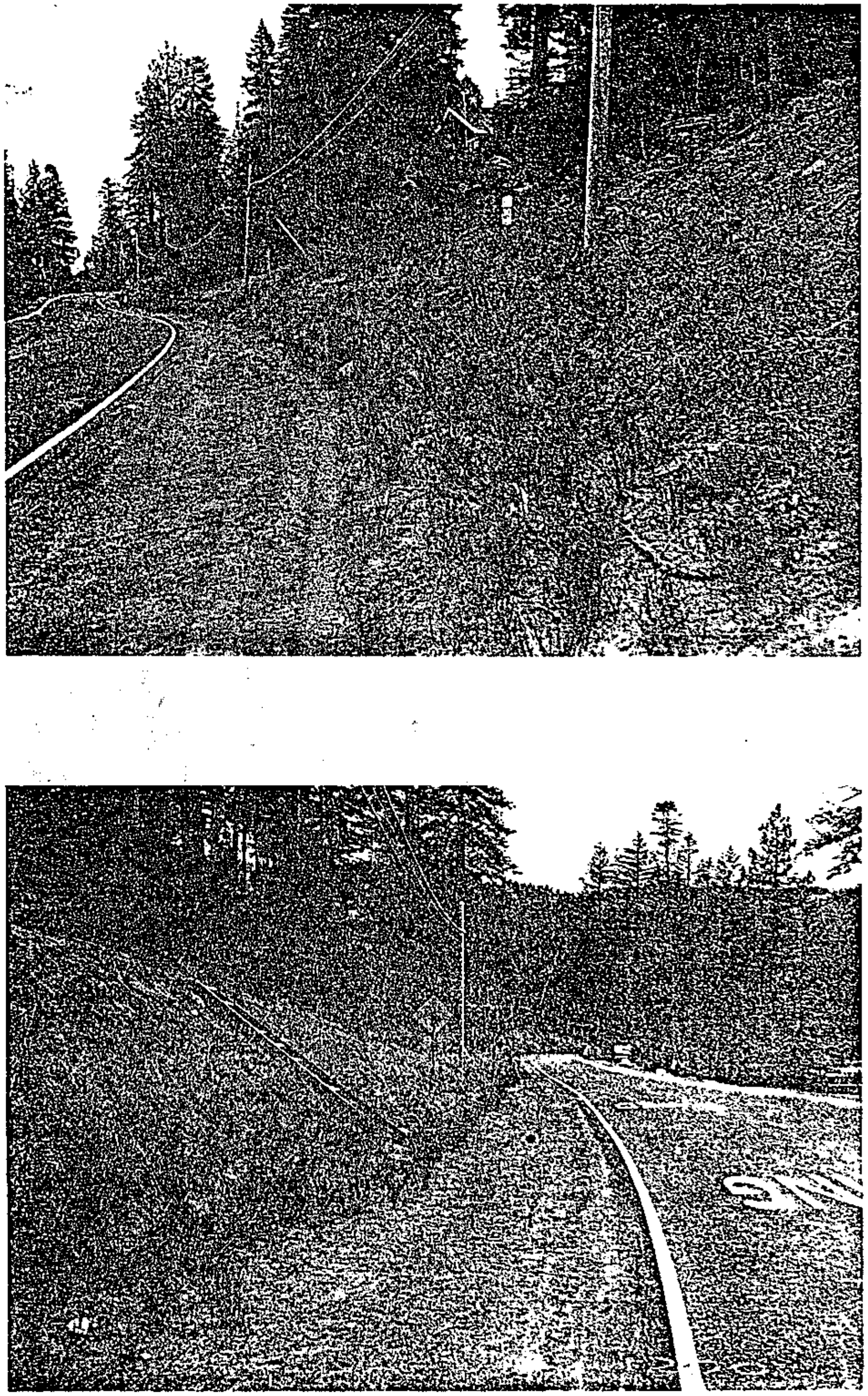


Figure 1. PLA 1.18-1.42. Note excellent grass cover and good slope stability.

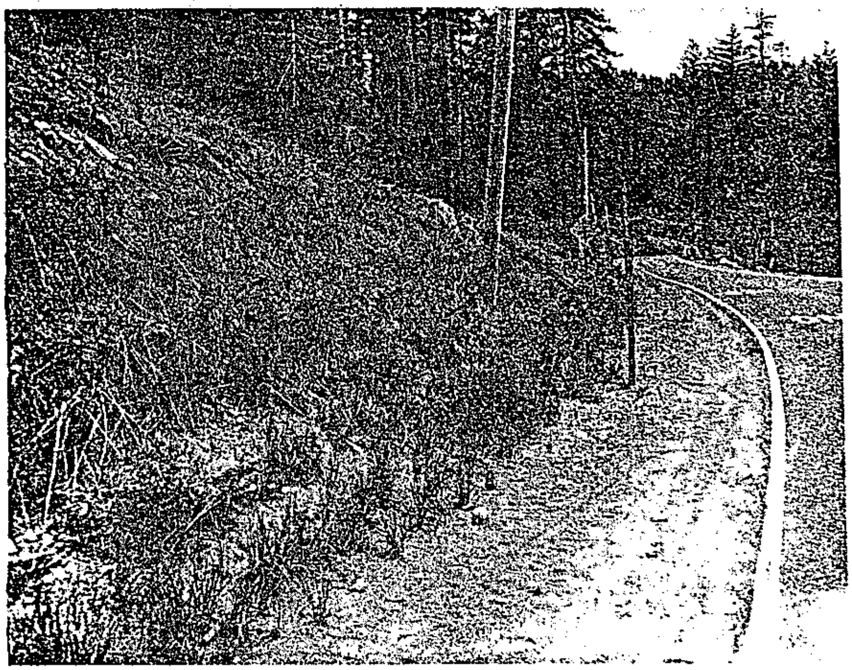
PLA 1.18 - 1.42

This slope has a good grass stand, the predominant species being Potomac orchardgrass (Figure 1 and 2 top). There is a small amount of Durar hard fescue, and a trace of Sodar streambank wheatgrass. Portions of the slope have good stands of the transplanted shrubs, but grass constitutes most of the vegetative cover.

Portions of the slope, particularly those which were seeded to grass only, appear nitrogen deficient. Plant cover on all of the slope would improve if fertilized with 16-20-0 at 250-500 lb/acre. There does not appear to be a difference between the slow release fertilizer (urea formaldehyde 38-0-0, 80 lb/acre N) and 16-20-0 (40 lb/acre N) which was applied in October 10, 1973, even though the 38-0-0 was applied at twice the rate of nitrogen. Both had been refertilized with 16-20-0 (250 lb/acre) June 7, 1973 because they appeared nitrogen deficient.

There is little if any difference between the erosion control mats. The hydroseeding is very satisfactory and the Hold/gro unsightly even after 5 years (Figure 2 - bottom). All treatments seem to suffer from being buried in de-icing sand, as well as needing fertilizer. Ground cover (slope protection) has reduced from the 6-9% in 1975 to about 1%. Fertilizing would result in at least partial recovery.

The top few feet is still a problem. The best results are the transplants of Barton western wheatgrass at about PLA 1.38. The rhizomes are creeping and the original transplanted clones have lost their identity. This is a weedy appearing species as it accumulates dry matter, but gives excellent protection. More experimentation should be done with this technique using other species.



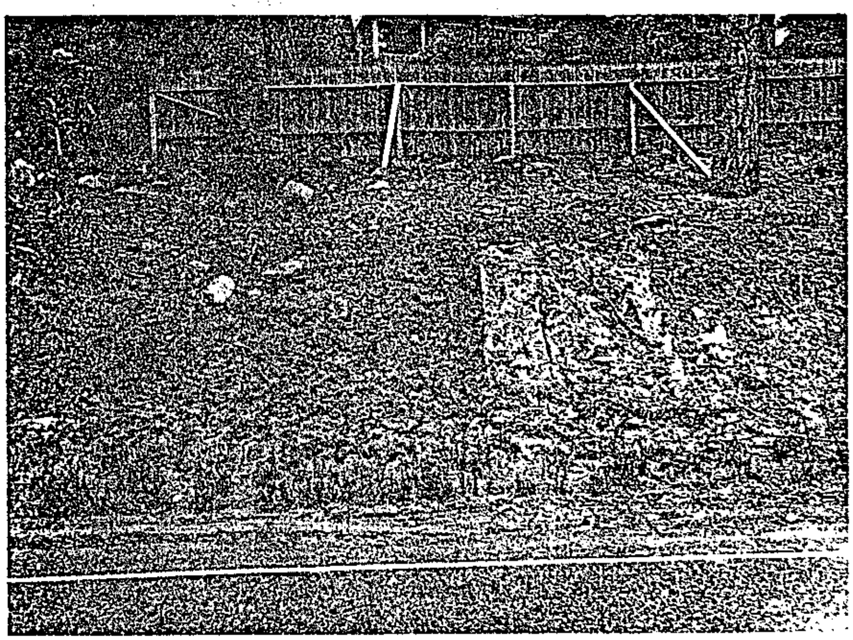


Figure 2. PLA 1.18-1.42 top-note excellent grass-willow wattling combination. Bottom compares hydroseeding left, with excelsior center, and hold/gro which is still painfully visible on right.

Table 1. Grass stand evaluation of experimental watersheds - June 1977.

Location	Treatment[1/]	Stand[2/] 1-10		Height-inches		Ground[3/] cover-%		Dominant grass species
		1975	1977	1975	1977	1975	1977	1977
PLA 1.27-1.42	Spring	6	8	9	10	6	10	orchard
	Fall	8	8	7	11	20	10	orchard
	Excelsior mat	8	5	4	4	6	1	orchard
	Paper mat	8	5	4	4	6	1	orchard
	Hydroseeding check	10	7	4	4	9	1	orchard
PLA 1.18-1.27	Spring	6	8	11	10	10	12	orchard
	Fall	8	9	12	15	18	15	orchard
ED 2.11	Fall	6*	5*	11	10	0-100	5	bluegrass and
	Spring	6*	5*	9	10	0-100	9	wheatgrass
ED 2.93-2.99	Fall	4	3	5	8	2	4	orchard and
	Spring	2	4	7	8	<1	5	fescue
ED 4.30-4.37	Fall	1	4*	10	8	<1	1-10	orchard
	Spring	1	3*	10	8	<1	1-10	orchard
ED 4.37-4.	Fall	2	5*	9	7	2	4	orchard
	Spring	3	6*	9	7	2	5	orchard
	Excelsior mat	8	6*	6	7	10	1	orchard
	Paper mat	7	6*	6	7	10	1	orchard

*Much poorer on top

1/ Each shrub transplanting zone (fall and spring shrub transplants A-G) on Dr. Leiser's map was evaluated separately and a mean value inserted in this table.

2/ Grass stands were rated 1 = no grass, 10 = excellent.

3/ Ground cover is the estimated percent of the ground covered by live plants.

This is not an experimental watershed, but has been the site of erosion control chemical and grass transplant experiments. Original results of the numerous fall 1971 hydroseeding treatments were very poor. However, the few original grass plants which become established have increased in size and in the case of rhizomatous species spread considerably. The resulting change in appearance is outstanding (Figure 3).

This is also the site of the original wheatgrass transplants of the Spring of 1973. Survival is excellent. Of the original 130, one died and 20 were washed out by the diversion from the top-of-cut ditch. There is little or no change since 1975. The grass is collecting a lot of soil, but is not spreading beyond the orignal seeded areas.

The transplants of April 15, 1974 did not do as well as those of 1973. The site eroded faster than the transplants could become adequately rooted. In 1975 many of the peat pots were lying on the surface, and the soil eroded away. More experimental work should be done with deeper rooting systems--utilizing long plastic tubes rather than peat pots. Plant numbers were drastically reduced by 1977 (Table 2). All survivors are in the bottom rows. Fertilized transplants did better than non-fertilized. Fertilizer was particularly important to Barton western wheatgrass. Average survival of all species was 19% if not fertilized, but 36% if fertilized (1975) and 4% and 18% in 1977. Best survival was with Western wheatgrass. Survival would have been much greater had it not been for the water coming over the top. A functioning top-of-cut ditch is a must if this upper portion is to be stabilized.

Table 2. Effect of fertilizer on survival of wheatgrass transplants one year and three years after planting.

	No fertilizer		Fertilized*	
	1975	1977	1975	1977
Barton western wheatgrass	5	3	35	35
Sodar streambank wheatgrass	33	10	36	10
Topar pubescent wheatgrass	19	0	37	10
Mean	19	4	36	18

*5 grams 21-8-8 in transplant hole.

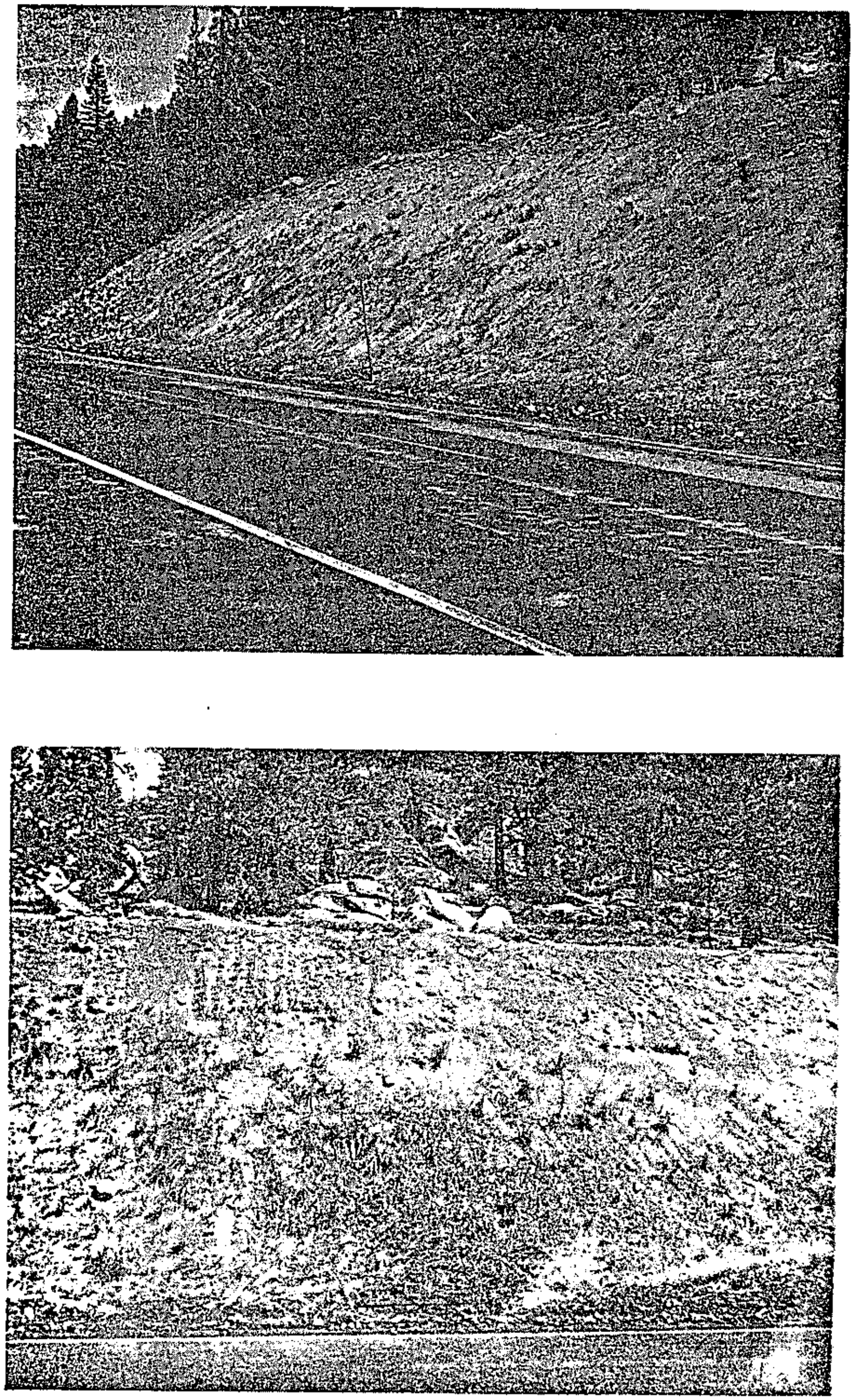


Figure 3. ED 1.94. Top shows considerable grass cover resulting from spread by rhizomes from original poor stand. Bottom shows excellent establishment of grass transplants in the difficult top-of-cut position.

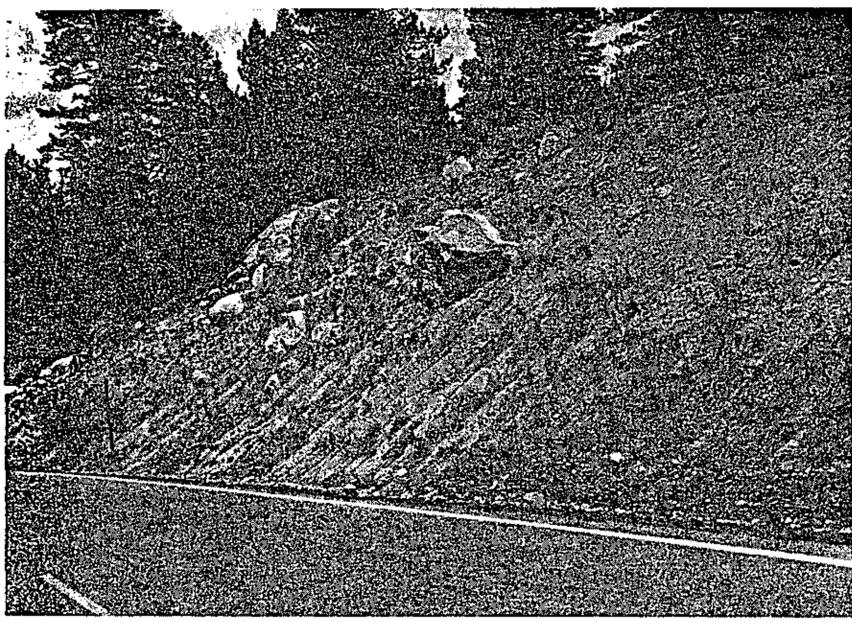
ED 2.11

Because the original seeding results were very poor, this watershed was reseeded. The effects of the second seeding (Oct. 10, 1973) were outstanding. The seed mix of Oahe intermediate wheatgrass (15 lb/acre), Topar pubescent wheatgrass (20 lb/acre) and Sherman big bluegrass (15 lb/acre) makes it obvious that most of the grass resulted from the second seeding. The spring planting of shrubs and/or poor growing conditions necessitated the second seeding. Results are still poor on much of the top one-third but good on the lower portion (Figures 4-top). Wheatgrass is doing best on the upper portion and big bluegrass and hard fescue on the lower one-half. The big bluegrass is providing the most total cover noticed on any of the watersheds, up to 100% on the best sites. This was also true on the Ward Valley experiments. Dry grass from past years is still providing protection. Shrub establishment is poor and grass provides most of the plant cover. Although refertilized with 80 lb of N in October, 1973 as 38-0-0, plant cover could be increased with an application of 250-500 lbs/acre of 16-20-0.

ED 2.93-2.99

Stands are very poor on both the spring shrub transplanted areas and the fall transplanted areas (Figures 4-bottom). Initial germination was excellent on the grass seeding (germinated beneath the snow) but stands have deteriorated each year. Potomac orchardgrass is the dominant grass species, with some hard fescue. Willows are responsible for most of the green color. Snow leaves this slope at a very late date, which may make it less suitable for growing grass.

If there is a difference between the 16-20-0 and 38-0-0 fertilizer treatments, it is the 16-20-0 which is darker green even though the 38-0-0 was applied at 80 lbs N and the 16-20-0 at 40 lbs. Both had equal amounts of phosphorus and sulfur.



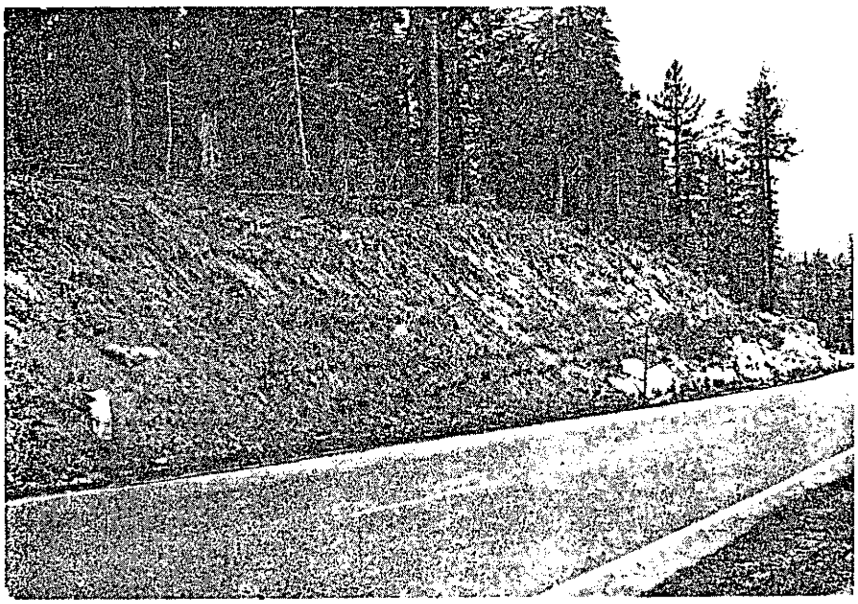


Figure 4. Top ED 2.11. Note fair to good stand of big bluegrass on lower one-half of slope and contribution of the grass litter, white upper one-half remain bare. Bottom ED 2.93-2.99 has poor grass but excellent willow growth.

ED 4.30-4.37

This has always been a very cold site and does not seem well suited to grass growth. Even though seeded 2 or 3 times, it is much less successful than the adjacent 4.37-4.45 which is around enough of a curve to be a more desirable aspect. Potomac orchardgrass is the dominant species. Shrubs by contrast are doing very well, but provide a minimal ground cover (Figure 5-top).

ED 4.37-4.45

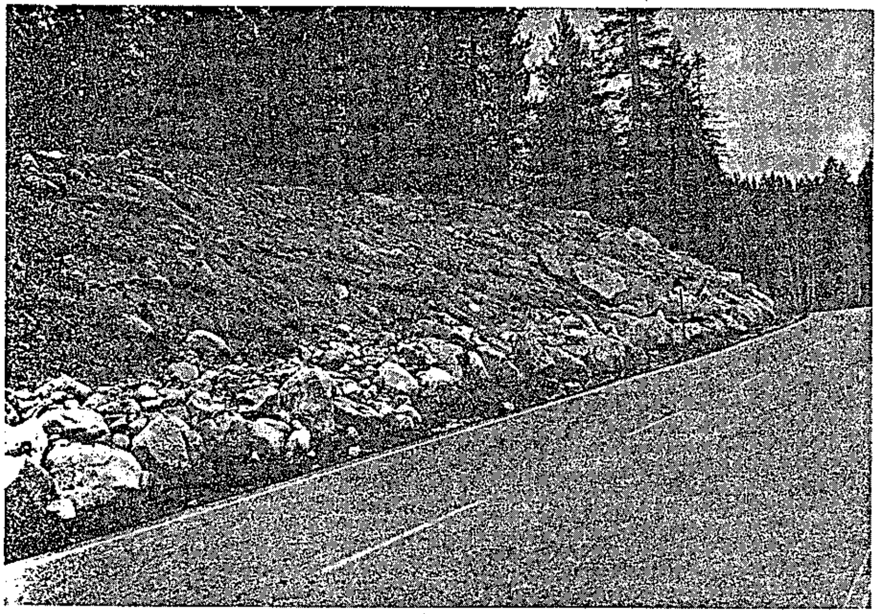
The dominant species (99%) is Potomac orchardgrass (Figure 5-bottom). Grass stands have generally improved since 1975, apparently from the excellent stand of orchardgrass seedlings noted at that time. These may be from seed which has carried over from the original seeding or some produced on the site. There were so many that I suspected at least some are from carryover seed. Stands of old grass were poor in 1975. An application of 16-20-0 at 250-500 lb/acre would increase the ground cover.

By contrast the grass stands are deteriorating in the excelsior and Hold-gro treatments. They particularly need fertilizing probably because of the excellent growth in past years . The heavy accumulation of de-icing sand noted in the mats in 1975 is still present, but no worse. Assuming all de-icing sand used in 1976-77 was black, there was none accumulated on this site during this period. The Hold/gro fibers (applied in the fall of 1971) are still very strong, although the mat has broken down. The excelsior fibers are still present in short segments.

Overall plant cover on this slope is about 50% grass and 50% shrubs.

ED 2.44

This large watershed was treated by Caltrans with numerous willow wattles and cuttings and seeded to a mixture of Topar pubescent wheatgrass (16



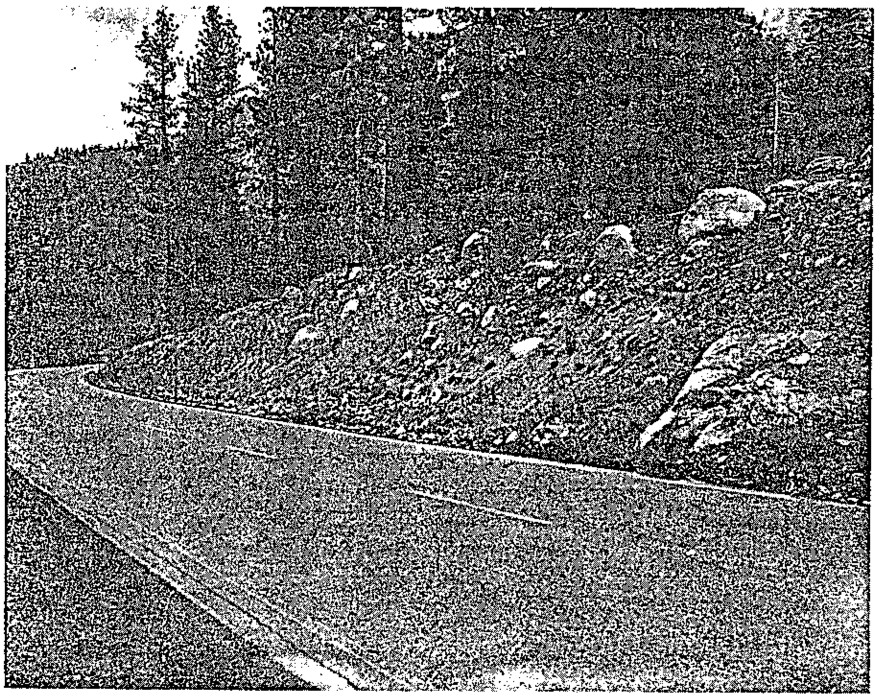


Figure 5. Top (ED 4.30-4.37) has very poor grass stands, while on bottom (ED 4.37-4.45) the grass stand is improving.

lb/acre), Oahe intermediate wheatgrass (15 lb), Potomac orchardgrass (10 lb), and Sherman big bluegrass (2 lb) early in the summer of 1973. Observations in 1975 noted less grass and more willow on the north compared to the south and grass seedlings were common. Current observations indicate 80% of the cover on the north is grass and 50% on the south, the remainder being willow. The dominant grass on the north is orchard and wheatgrasses dominate on the south. A considerable portion of the slope protection is from grass litter (dead grass - mostly orchardgrass from last year).

A number of new wattles and willow cuttings were added recently to a few critical areas. However, these areas do not appear to have been seeded with grass. I suggest these areas should be seeded and the entire watershed fertilized. A convenient method of fertilizing might be with 250-500 lbs/acre of 16-20-0 in water if you have a hydroseeder present to plant the new wattles.

Also there is a fiberglass treatment on one edge which is unsightly. I suggest a policy of seeding grass before any such experimental treatment. This would allow observations on the effectiveness of the treatment for plant establishment as well as erosion control, and would also improve appearances. Grass was apparently seeded with the fiberglass at ED 22.8 (Newhall cut?) which looks much better in spite of the unsightly fiberglass.

II. Grass Nurseries

The large nurseries at the Tahoe airport and Tahoe Keys, planted November 18, 1970 and March 9, 1971 respectively, were rated for stand (1 = none, 10 = excellent) on June 11, 1975 and on June 7, 1977. It is obvious from table 3 that there are many well adapted species, nearly all of which are commercially available. The wheatgrasses such as Luna, Topar, Greenar, Oahe and Tegmar as well as smooth brome varieties continue to do well. The orchardgrasses and Durar hard fescue are slowly disappearing as expected, but gave excellent

Table 3. Stand of erosion control species in Tahoe nurseries, June 1975 and 1977. (10 = excellent, 1 = no plants).

GRASSES	TAHOE KEYS			TAHOE AIRPORT		
	1973	1975	1977	1973	1975	1977
1. Western wheatgrass - Colorado	3	3	3	5	7	6
2. " " 727	2	3	4	4	5	6
3. " " P-14897	1	1	1	1	1	1
4. Nordan crested wheatgrass	8	6	4	10	9	9
5. Greenar intermediate wheatgrass	10	8	8	10	10	10
6. Amur " "	8	8	6	4	6	2
7. Oahe " "	10	8	8	10	8	9
8. Tegmar " "	9	8	7	10	8	9
9. Topar pubescent wheatgrass	8	7	7	10	10	10
10. Luna " "	10	9	10	10	10	9
11. Trigo " "	10	10	8	9	8	10
12. Alkar tall wheatgrass	8	7	6	9	8	8
13. Largo " "	10	8	8	10	9	9
14. Whitmar beardless wheatgrass	7	7	7	9	8	7
15. Siberian wheatgrass	8	5	4	9	7	7
16. Primar slender wheatgrass	2	1	1	5	4	1
17. Sodar streambank wheatgrass	7	6	6	9	7	7
18. Potomac orchardgrass	8	2	2	8	5	5
19. Akaroa "	3	1	2	9	4	5
20. Latar "	6	3	2	7	6	5
21. Pomar "	2	1	1	9	4	3
22. Lincoln smooth brome	7	6	6	5	5	6
23. Liso smooth brome	8	6	5	9	9	9
24. Manchar smooth brome	5	4	4	9	9	9
25. Polar brome	4	3	3	-	-	-
26. Bromar mountain brome	5	2	1	6	5	2

Table 3 (continued)

GRASSES	TAHOE KEYS			TAHOE AIRPORT		
	1973	1975	1977	1973	1975	1977
27. Durar hard fescue	7	6	5	9	9	7
28. Boreal red fescue	8	4	4	–	–	–
29. Arctared fescue	2	1	1	–	–	–
30. Creeping red fescue (Oregon grown) 4	7	4	3	–	–	–
31. Climax timothy	4	3	1	8	4	4
32. Sherman big bluegrass	8	8	8	6	6	6
33. Kentucky bluegrass	4	1	1	5	4	4
34. Nugget bluegrass	2	1	1	–	–	–
35. Wimmera 62 ryegrass	5	1	1	1	1	1
36. Manhattan perennial ryegrass	8	1	1	–	–	–
37. Russian wildrye	1	1	1	1	1	1
38. Red top	4	1	1	–	–	–
39. Elymus triticoides P-15593	1	1	1	–	–	–
40. " " P-15594	1	1	1	–	–	–
41. Puccinellia	1	1	1	–	–	–
42. Deschampsia	1	1	1	–	–	–
43. Nugains winter wheat	1	1	1	1	1	1
44. Tetra Pekus cereal rye	1	1	1	1	1	1
45. Barton Western Wheatgrass	1	1	1	4	4	6
LEGUMES						
1. White clover (Idaho grown)	7	1	1	1	1	1
2. Alsike clover	8	1	1	3	3	2
3. Red clover (Chesapeake)	5	1	1	5	2	2
4. Cicer milkvetch PI-288-66	3	1	1	3	3	2
5. Sainfoin	4	1	1	2	2	2
6. Rambler alfalfa	9	2	2	2	2	2
7. Ladac alfalfa	6	2	2	2	2	1
8. Black medic	2	1	1	2	1	1
9. Flat pea	2	1	1	–	–	–
10. Strawberry clover	2	2	1	–	–	–

initial cover. Sherman big bluegrass continues to do well. Many others are disappearing at both sites. Western wheatgrass (strain 727) is increasing at both sites.

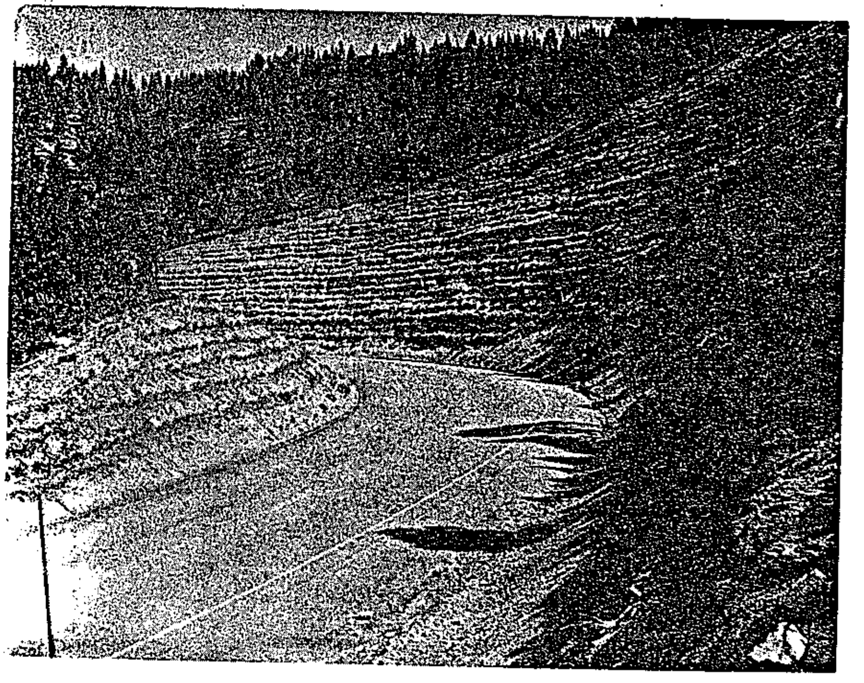
None of the legumes persist in adequate numbers to contribute to nitrogen fixation or erosion control.

III. Kingsbury Fertility Study

On April 20, 1972, a fertilizer trial was established on an old stand of wheatgrass. Three replications were drill planted in the fall of 1970, and two reps hydroseeded on a fill slope in about 1969. All appeared very nitrogen deficient in April 1972 when fertilizer was applied at 100 lb/acre nitrogen (in addition to the fertilizer used at planting time). Following are the treatments and a visual rating (1 = yellow, very nitrogen deficient, 10 = dark green indicating adequate nitrogen).

	Mean Rating	
	June 1975	June 1977
Urea formaldehyde (38-0-0) plus single superphosphate.	8	7
MagAmp (7-40-6) plus soil sulfur.	10	8
Check - no fertilizer.	3	4
Ammonium-phosphate-sulfate (16-20-0).	10	9
Ammonium sulfate (21-0-0).	10	8
Sulfur coated urea (34.7-0-0) plus single superphosphate.	9	9

All fertilizer treatments appear satisfactory, but urea formaldehyde is obviously not supplying nutrients at the same level as the others. The check plots are deteriorating to the point where ground cover is significantly reduced and erosion control is minimal. Even with a rating of 10 the ground cover is only about 10%, so site protection is minimal.



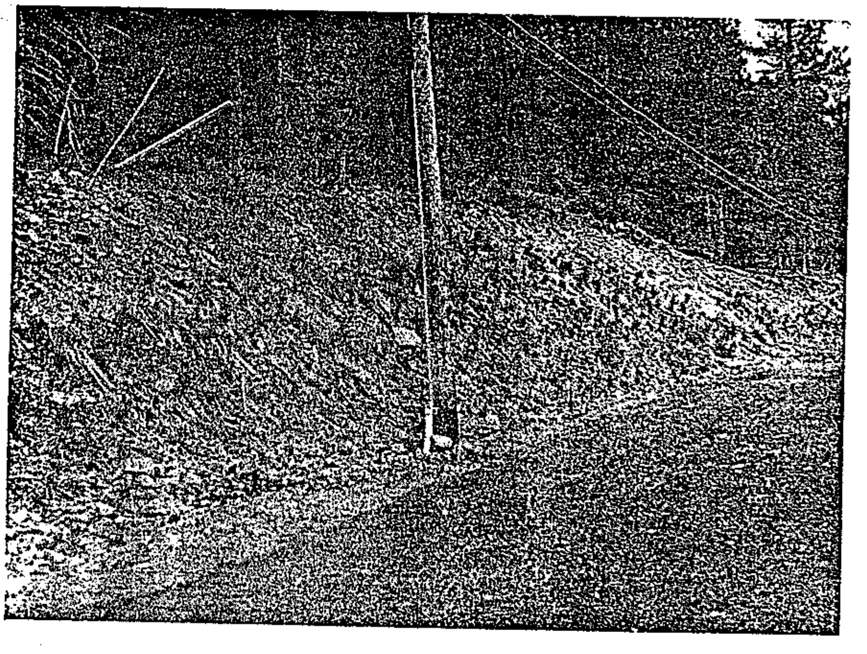


Figure 6. Top Kingsbury Grade showing deterioration of benches and poor stand of grass on right (south slope) and good grass on left (north slope). Lower photo is Ward Valley showing grass stand which eventually developed from a poor start. Top-of-cut is still a problem.

IV. Kingsbury - general observations

Step construction is proving questionable at this site (Figure 6-top). The grainite is too soft to stand alone, and although excellent grass stands were generally obtained the steps have sloughed off and little grass remains. Exceptions are natural seeps and north-facing slopes which have excellent grass stands. The rhizomatous grasses show an inclination to spread uphill in the bench talus, but masses of exposed roots are common on the lower side of the bench. A complete collapse is probable and a smooth, bare, slope is inevitable.

Fill slopes are benefited greatly by the short sections of fence. The rhizomes of pubescent and intermediate wheatgrass are spreading well.

Shrubs were transplanted on a fill slope in April 1973 by Dr. Jim Young of ARS-USDA, Reno. Survival percentages (June 1977) are in Table 4.

Table 4. Survival of shrub transplants - Kingsbury Grade.

Species	Number Planted	Survival Percent
Curl leaf Mt. Maghogany	12	0
4-wing saltbush	6	33
Desert peach	39	54
Hopsage	6	0
Gray and green rabbitbrush	120	18

Grass variety tests show Sherman big bluegrass to be the best adapted and spreading. Durar hard fescue, smooth brome, Oahe intermediate wheatgrass, orchardgrass, and Nordan crested wheatgrass are doing well.

Shrubs volunteering on fill slopes are rabbitbrush, bitterbrush and _Ceanothus veluntinus_.

V. Ward Valley

Erosion control treatments and results are similar to the discussion of ED 1.94 (Figure 6-bottom). Even though initial success was poor the plants have spread, primarily by rhizomes, until the appearance of the slope is much improved. However, erosion continues but at a reduced rate. This is a very steep slope (1.5:1 ?).

Grass varieties which are outstanding are Sherman big bluegrass which is spreading and Oahe intermediate wheatgrass. Both varieties are very productive and the litter remaining from previous years offers a great deal of protection. Erosion is nil. Fertility is inherently much better than any of the other sites reported.

VI. Discussion and Summary

Grass varities which continue to look good at all sites are Potomac orchardgrass and Sherman big bluegrass. These were originally seedbed as temporary cover, but have survived or spread better than the wheatgrasses which were to replace them.

Fertility has declined as expected on many sites. Original plans suggested that shrubs which have a lower fertility requirement would replace the grass. It is still too early to tell if this will happen other than the old fill slopes at Kingsbury where rabbitbrush is taking over (not seeded). Some slopes on Luther and Chamberlin were not seeded to shrubs and should be fertilized to protect the site.

My original attitude about both grass varieties and fertilizer have changed. I initially felt we should seek short-growing grass varieties to minimize contrast with the forest environment. We were also extremely conservative on the use of fertilizer. From the 1975 and 1977 evaluations it is obvious that ground cover of living plants will never be better than minimal (10-20% is the best we've achieved). I now suggest we use the most productive grasses and fertilize them well. The most productive grasses would be

Sherman big bluegrass, Potomac orchardgrass and Oahe intermediate wheatgrass. Instead of the original 250 lb/acre of 16-20-0, I would suggest 500 lbs (we always had to add the other 250 lbs the first or second year anyway) and 250 lbs/year thereafter. This should achieve a production level which would accumulate grass litter which would far exceed the ground cover of green grass (50% cover of litter is realistic).

Fertilizer should continue to be 16-20-0 because of the good balance of nitrogen (16%) phosphorus (20% P_2O_5) and sulfur (12%). All of these elements are deficient in soils of the Tahoe Basin and to leave one out would result in inefficient use of the others.

Step construction is not practical in this area as the decomposed granite is not strong enough to stand alone. Willow wattling continues to be an effective tool.

The use of grass transplants continues to show the most promise to stabilize the top-of-cut position. More experimental work should be done looking at longer planting tubes and fertilization practices.

The use of excelsior or Hold/gro does not seem justified. Results are similar to hydroseeding alone; thus the additional cost cannot be justified.

Shrub transplants should include rabbitbrush, desert peach, and 4-wing saltbush where adapted as they are doing well at Kingsbury Grade.